(12) UK Patent Application (19) GB (11) 2 011 589 A

(21) Application No **7848401**
(22) Date of filing **13 Dec 1978**
(23) Claims filed **13 Dec 1978**
(30) Priority data
(31) **7739773**
(32) **30 Dec 1977**
(33) **France (FR)**
(43) Application published **11 Jul 1979**
(51) **INT CL^2 F02K 9/04**
(52) Domestic classification **F3A** 10E 10F 10L5 10N 10R2
(56) Documents cited **None**
(58) Field of search **F3A**

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(54) **Propulsion unit and process for the acceleration of a missile**

(57) A propulsion unit 2 for the acceleration of a missile 1 comprises a body 7 connected by a shear connection 6 to a cruising stage of the missile and supporting a propellant charge consisting either of tubular elements 10, 11 stuck on an inhibiting ribbon 13 which is sprially wound or plates of propellant arranged in the form of a star, the charge being located within a cylindrical envelope formed, as shown, by a launching tube 3 without a nozzle and closed at the rear end by a frangible cover 20. The charge is initially ignited under conditions which permit a stable combustion of the propellant, the charge continuing to burn for a duration of less than one second under conditions which theoretically correspond to an unstable combustion of the propellant. Maximum and minimum values for the ignitable surface area of the propellant are specified.

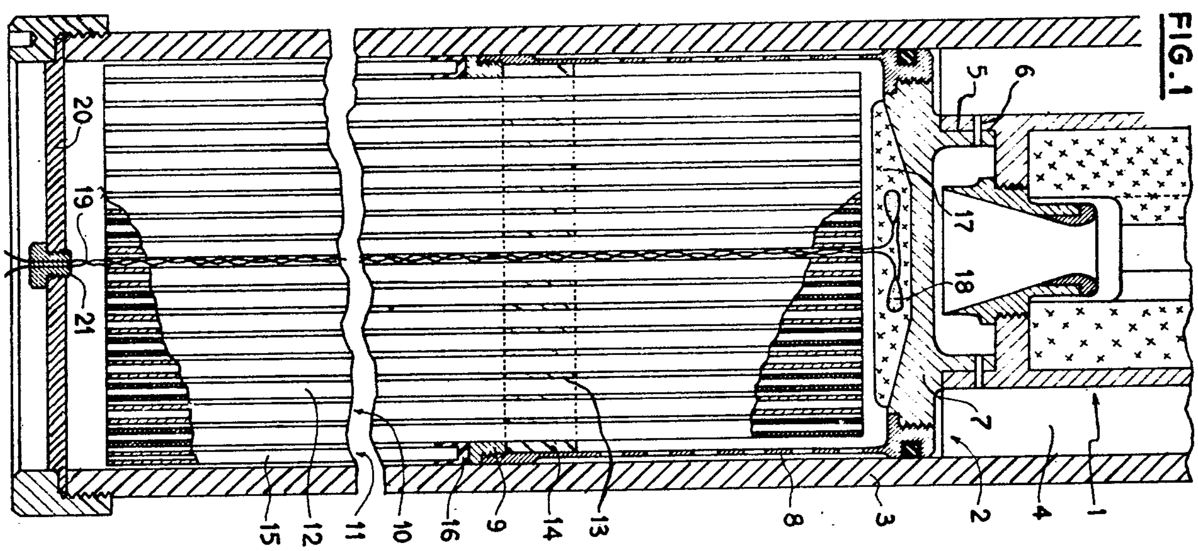

FIG.1

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FIG. 1

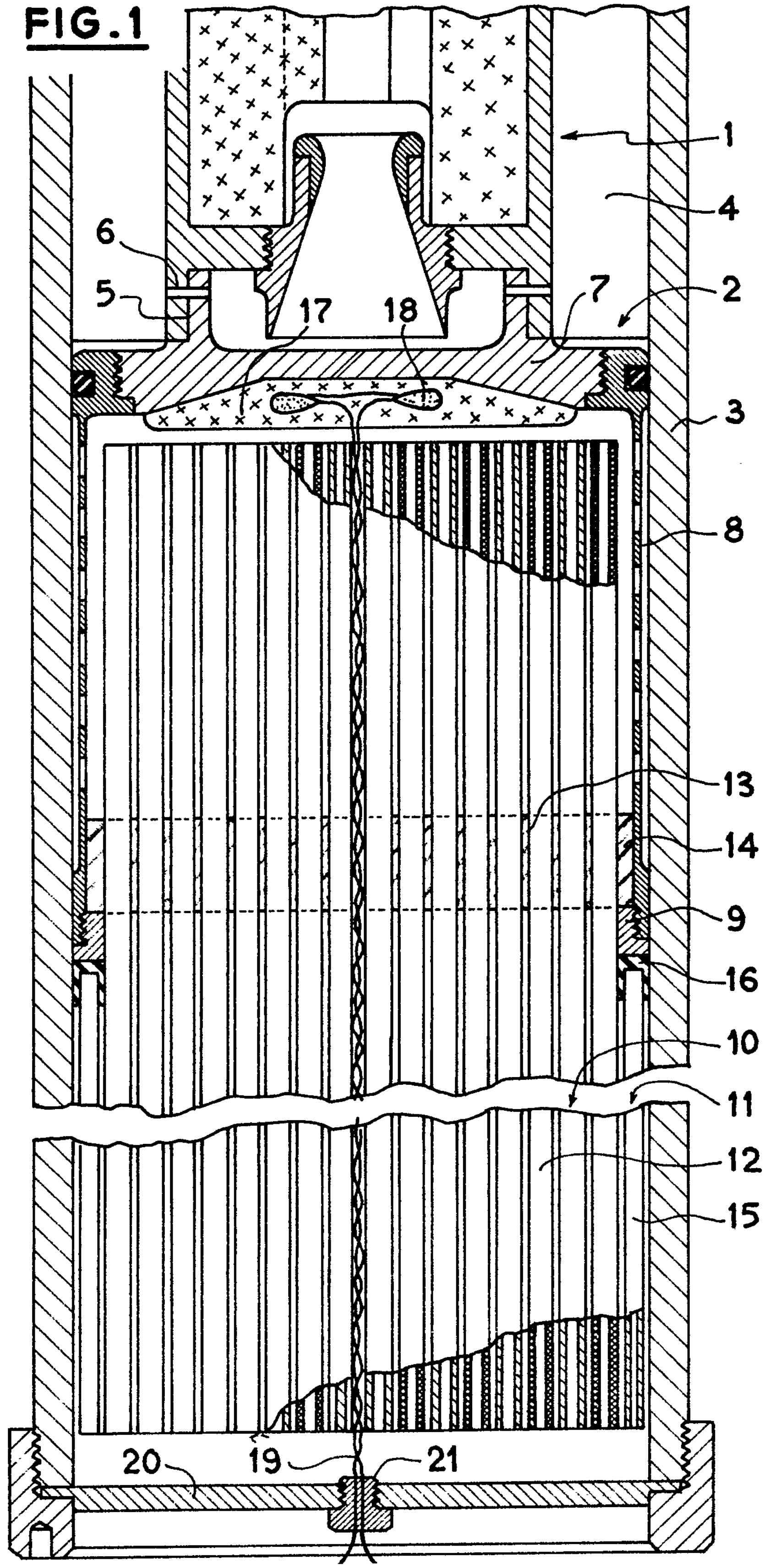


FIG. 2

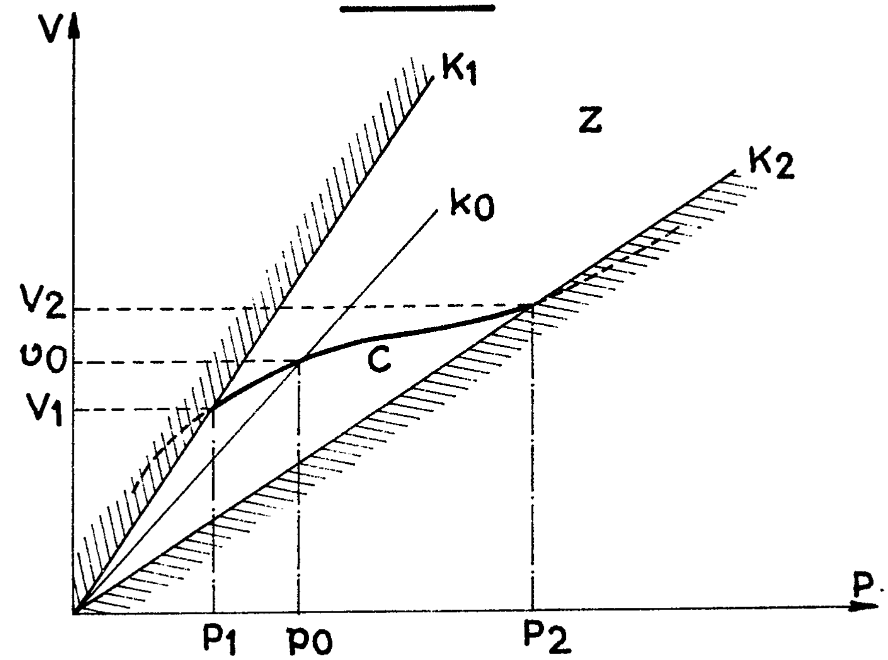


FIG. 3

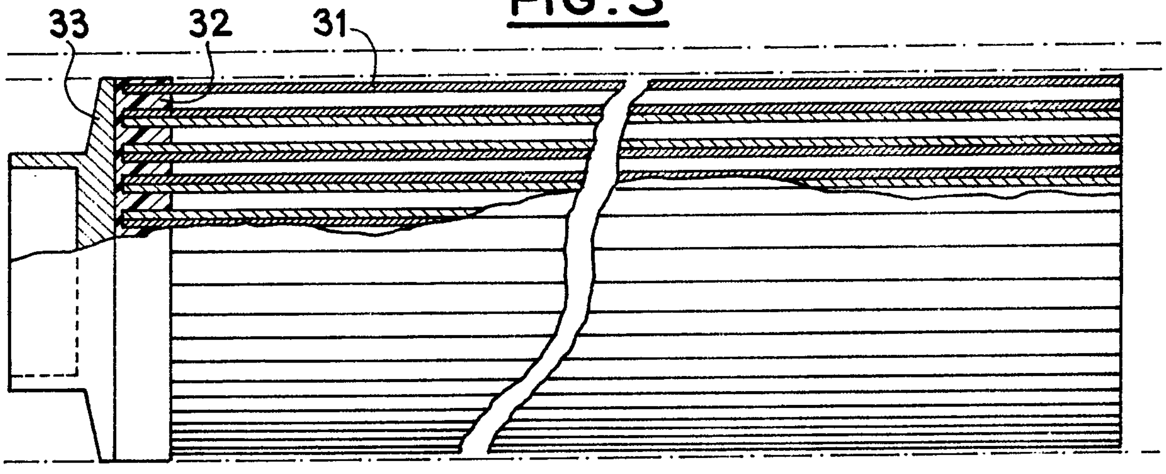
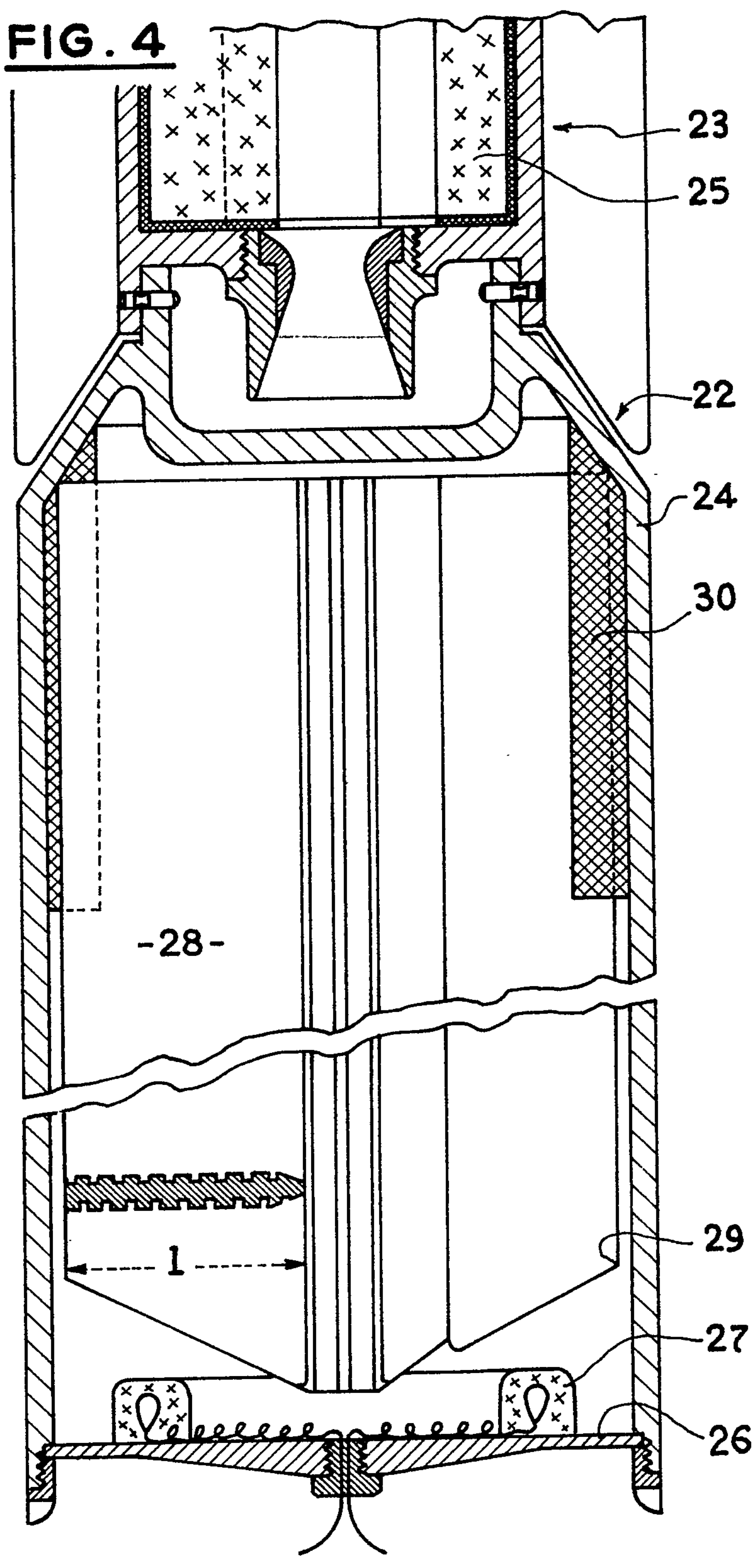


FIG. 4



SPECIFICATION

Propulsion unit and process for the acceleration of a missile

This invention relates to the propulsion of missiles by means of a propellant charge produced from solid propellant, and more especially relates to propulsion units for the acceleration of self-propelled missiles, in particular missiles fired from a launching tube.

Self-propelled missiles, such as guided missiles or rockets, most frequently comprise two separate stages, namely, an acceleration stage which is subsequently released during the flight of the missile, and a cruising stage which contains the useful load. Although the cruising stages always comprise a conventional propulsion system including a body outside the charge, which withstands the pressure of the combustion gases and is equipped, in its downstream part, with at least one nozzle for the ejection of the combustion gases, this is not the case of the acceleration stages of missiles which are fired from launching tubes. In fact, such acceleration stages can comprise a propulsion system, the body of which does not have to withstand the pressure of the combustion gases, this pressure being exerted instead directly on the internal surface of the launching tube, and the body of the propulsion system only has to hold in place a nozzle for the ejection of the gases, it being possible for this nozzle to be either a conventional central nozzle, or an annular nozzle which is formed by a free passage between the internal surface of the launching tube and a central bulb or an annular bulb integral with the body of the propulsion system. Such acceleration stages, in which the body of the propulsion system does not have to withstand the pressure, are of particular value because it is possible to lighten the body of the propulsion system, which is then acted upon only by the pulling force resulting from the action of the gases on the convergent parts of the nozzles. This lightening of the body of the propulsion system enables a reduction of its transverse cross-section, which makes it possible to increase the cross-section available for housing the propellant charge, despite the very large longitudinal pulling forces which are generated in the acceleration stages.

As regards missiles fired from a launching ramp or from a simple caisson, and missiles which are fired from a launching tube but for which the combustion time of the propellant charge for acceleration is greater than the time for which the missile moves in this tube, it is necessary for the bodies of the propulsion systems of these missiles to support both the radial forces generated by the pressure being exerted on the side surface of the body of the propulsion system, and, the longitudinal forces generated by the pressure being exerted on the convergent parts of the nozzles. This double orientation of the stresses makes it necessary to produce a propulsion system with a very strong body and, as a result, for a given maximum cross-section of the missile, the large thickness of this body required to provide the necessary strength means a smaller cross-section available for housing the propellant charge. Furthermore, when the body of the propulsion system is made of a composite material comprising webs of high-modulus fibres, it is necessary to provide a large number of intersecting webs in order to enable the body of the propulsion system to withstand the radial and longitudinal stresses.

According to the present invention there is provided a propulsion unit for accelerating a self-propelled missile, comprising a body, a propellant charge including separate elements of propellant and carried on the body, and a generally cylindrical envelope surrounding the charge and capable of withstanding the pressure of the gases produced by combustion of the charge, the envelope including an opening for the ejection of the combustion gases from the envelope, the ignited surface area of the charge being between minimum and maximum values obtained by multiplying the initial free cross-section for the ejection of the gases, measured in the region of the ends of the elements of propellant, by the minimum and maximum coefficients of compression for the composition of the propellant of the elements, and the cross-section of the ejection opening being approximately equal to the cross-section of the envelope portion arranged around the propellant charge.

By avoiding longitudinal stresses which must be withstood by the bodies of propulsion systems for acceleration, it becomes possible to reduce the thickness and the length of these bodies and therefore simultaneously to reduce the dead weight of the acceleration stage and increase the volume available for housing the propellant charge for acceleration. These advantages, which are substantial for acceleration stages in which the body of the propulsion system constitutes the envelope and supports the pressure of the gases, become even greater for acceleration stages in which the pressure is withstood by a launching tube, because in this case, the body of the propulsion system can be reduced to a simple device which carries and positions the propellant charge in the launching tube and ensures that the thrust is transferred to the cruising stage of the missile.

The invention can be carried out by using propellant charges of known composition and the general shape, but the dimensional characteristics of which ensure a special process of combustion which results partly from the discovery that, if a charge is initially ignited under conditions which permit a stable com-

bustion of the propellant of this charge, it is possible for the charge to continue burning for a short period of time under conditions which theroretically correspond to an unstable combustion of this propellant. Experiments undertaken have shown that this new process of propulsion entails only a small reduction in the total impulse produced by the combustion of the pyrotechnic charge, and that this reduction can be compensated by the increase in size of the propellant charge, which is made possible by the increase in the volume available for housing the propellant charge.

The advantages gained by carrying out the invention become more significant, the shorter the total combustion time of the charge. Beyond a combustion time of two seconds, the new process of propulsion no longer seems to be suitable, despite the wide choice of propellant compositions which are available.

The invention also provides a process for the acceleration of a self-propelled missile, consisting of burning a propellant charge, which comprises separate elements of propellant and is fixed to a body of the propulsion system, in an envelope which withstands the pressure of the gases produced by the combustion of the charge and has an opening for the ejection of the combustion gases from the envelope, and wherein, at the moment of ignition, the surface area of the charge is between the minimum and maximum values obtained by multiplying the initial free cross-section for the ejection of the gases, measured in the region of the end of the elements of propellant, by the minimum and maximum coefficients of compression for the composition of the propellant elements, respectively, and throughout the combustion of the charge, the cross-section of the ejection opening is approximately equal to the cross-section of the part of the envelope arranged around the propellant charge.

Preferably, the propulsion unit and the acceleration process are such that, during combustion, the instantaneous surface area of combustion of the propellant charge becomes less than the minimum value obtained by multiplying the instantaneous free cross-section for the ejection of the gases, measured in the region of the ends of the elements of propellant, by the minimum coefficient of compression of the propellant composition used.

More particularly, the geometric conformation of the elements of propellant is such that the instantaneous surface area of combustion of the charge is less than the said minimum value for a period of time which does not exceed one second. The best results have been obtained with a combustion time of less than one tenth of a second, and this covers all the applications of the invention to missiles fired from a launching tube, such as artillery rockets and anti-tank rockets.

According to a first possible embodiment, which is intended, on the one hand, for missiles fired from a launching ramp or from a simple caisson, and, on the other hand, for missiles which are fired from a launching tube but for which the combustion time of the propellant charge is greater than the time for which the missile moves in this tube, the cylindrical envelop forms part of the body of the propulsion system. It is then necessary for the opening in the body of the propulsion system to be temporarily blocked for as long as the propellant charge has not been ignited, it being possible to effect this blocking, for example, either by means of a cover which can shear, in the case where the body of the propulsion system forms part of the first stage of a self-propelled missile, or by means of part of the lower stage, in the case where the body of the propulsion system forms part of an intermediate stage or of the last stage of a propelled missile.

According to a second possible embodiment, the cylindrical envelop consists of an element of the launching tube for the self-propelled missile, it being possible for this element to form a direct part of the temporarily blocked launching tube, or for this element to be joined to the launching tube and form the container for transporting the self-propelled missile, the rear opening in this container possessing a blocking device which only frees this opening when the propellant charge is ignited. This blocking device is preferably a cover which can shear along a circumference corresponding to the internal surface area of the container.

The new process of operation employed in the propulsion unit according to the invention requires the use of a propellant charge possessing a very large surface area of combustion, and, preferably, there are at least ten disjoined elements of propellant forming this charge, in the case where these elements are blocks of star-shaped cross-section or grooved sheets, and at least fifty in the case where these elements are tubes of propellant. Since the flow-rate of the combustion gases is very high and the combustion gases are ejected at a supersonic speed, it is advantageous, on the one hand, that the elements of propellant be arranged parallel to the side surface of the cylindrical envelope, and, on the other hand, that each element of propellant has a constant transverse cross-section.

According to a particularly simple embodiment, all the elements of propellant have an identical transverse cross-section and all the elements of propellant are of identical composition; however, since the essential condition is that all the elements of propellant possess the same combustion time, it is possible to use mixed charges comprising elements of propellant of different shapes and/or of different compositions. A satisfactory embodi-

ment of the invention requires the use of propellants which simultaneously possess good mechanical properties and a high combustion speed which is greater than 10 millimetres per second, and homogeneous propellants, such as propellants based on nitrocellulose and on nitroglycerine, are particularly suitable. Good mechanical properties are required in order to form a propellant charge in which the elements of propellant do not consist exclusively of propellant, but it should be noted that it is possible to use weaker propellants, insofar as the method of fixing the elements of propellant to the body of the propulsion system is especially adapted, for example by increasing the number of fixing zones over the whole length of these elements or by strengthening these elements by means of a rigid strap which is preferably an internal strap. Composite propellants, that is to say those consisting essentially of plastic binder and an oxidising agent, can thus be used.

Preferably, if the total combustion time of the charge is greater than a few tenths of a second, at least one element of propellant possesses an instantaneous surface area of combustion which increases during the combustion of the propellant charge, these elements having an increasing surface area of combustion representing at least ten per cent of the total surface area of combustion of the charge, and an arrangement of this kind making it possible to limit the reduction in the instantaneous coefficient of compression of the charge. The increase in the instantaneous surface area of combustion of the elements of propellant can be achieved, for example, by partial inhibition of these elements. Propellant charges having shapes which are in themselves known are particularly suitable for carrying out the invention, in particular charges using elements of propellants in the shape of a tube of circular cross-section, or elements in the shape of a plate, which are fixed to the body of the propulsion system via a layer of inhibiting material.

The present invention is explained by the following examples for which:

Figure 1 is a view, in partial longitudinal section, of the rear part of an anti-tank rocket fired from a launching tube,

Figure 2 is a graph showing the combustion charactertic of a two-component propellant composition,

Figure 3 is a view, in partial section, of the propulsion element constituting the acceleration stage of a self-propelled missile fired from a launching tube, and

Figure 4 is a view, in section, of a stage for the acceleration in flight of a semi-self-propelled missile.

With reference to Fig. 1, the rocket comprises a cruising stage (1) to which an acceleration stage (2) is temporarily fixed, the whole being placed in the cylindrical container (3) which withstands the pressure of the gases and is fixed to the rear of the launching tube for the rocket. The cruising stage, which is in itself known, possesses an external diameter which is less than the internal diameter of the launching tube, and it is wedged axially by means of the stabilising fins (4). The two stages are temporarily connected by means of the cylindrical centering device (5) and the four shear pins (6).

The acceleration stage (2) comprises the body of the propulsion system, which consists of the front plate (7) to which is screwed the perforated shell (8) of the device for wedging the propellant charge, this shell being terminated at the rear by the supporting ring (9), on which is stuck the main charge (10), and under which is stuck the peripheral charge (11). The main charge consists of 300 tubular strands (12) of two-component homogeneous propellant, which are individually stuck to the flexible inhibiting ribbon (13) which is wound in the form of a spiral and strengthened on the outside by means of the inhibiting ring (14) stuck to the support ring (9). The peripheral charge consists of 85 tubular strands (15) produced from the same propellant as that used in the production of the tubular strands of the main charge, and these 85 strands are embedded in an annular inhibiting base-plate (16) which is stuck under the support ring (9). These propellant charges can be ignited by means of the igniter which is fixed to the front plate (7) of the body of the propulsion system and consists of a sachet of ignition powder (17), in which powder are placed two electrical ignition devices (18) connected to the electricity generator by means of the conductors (19) which pass through the main charge along the centre of the spiral and pass through the cover (20), which can shear, by means of a leak-tight passage (21). This cover, which can shear along a circumference equal to the internal diameter of the container (3), withstands the pressure of the gases required for the ignition of the propellant charges, the combustion of these charges therefore taking place without the use of any nozzle for the ejection of the gases.

Fig. 2 represents the usual shape of the curve (C) which shows, for a given ambient temperature, the speed of combustion (V) of a propellant composition as a function of the pressure (P) prevailing in the combustion chamber, this graph constituting the combustion characteristic of the propellant composition. On this graph, the lines K1 and K2 are the lines of limiting compression, which delimit between one another the normal zone of combustion (Z), the combustion of the composition being unstable or impossible outside this zone. These graphs, which are well-known to explosives experts, are determined experimentally using combustion chambers terminated by a nozzle of constant cross-

section, and the compression lines of the general equation V = K.P have a coefficient K which is called the coefficient of compression of the propulsion system and is equal to the following ratio: instantaneous surface area of combustion of the charge/area of the neck of the nozzle of the body of the propulsion system.

For a propellant charge of given conformation, the instantaneous coefficient of self-compression (ki) is given by the following ratio: instantaneous surface area of combustion of the charge/free cross-section at the downstream end of the charge, and it should be noted that this coefficient ki only affects the actual course of the combustion of a propellant charge placed in propulsion system comprising a nozzle insofar as it is less than the coefficient K of the propulsion system, that is to say insofar as the free cross-section at the downstream end of the charge is less than the area of the neck of the nozzle of the body of the propulsion system. As soon as this condition is no longer obeyed, the propellant charge departs from its normal combustion pattern and its mode of combustion is governed by the nozzle of the body of the propulsion system, the essential object of this nozzle being to keep the instantaneous coefficient K always between the limiting values K1 and K2, which are determined solely by the composition of the propellant used.

According to the present invention, it has been discovered, firstly, that it is possible to produce industrially propellant charges consisting of multiple strands of propellant, of which the initial coefficientof self-compression Ko is approximately equal to or greater than the coefficients K of the nozzle-type propulsion systems, and, secondly, that the instantaneous coefficient of self-compression ki of the charge can fall, for a short time, below the minimum coefficient of compression K1 of the propellant composition, without appreciably disturbing the combustion of these charges, the combination of these two conditions therefore making it possible to omit the nozzle of the propulsion systems for acceleration, which always possess a short combustion time.

These discoveries are based on multiple experiments and the following example is completely representative of the unexpected results which are derived from the two different modes of combustion, the charge in question being the main charge (10) of the missile shown in Fig. 1, and this charge consisting of 300 strands having a length of 200 millimetres, an external diameter of 5 millimetres and an internal diameter of 3 millimetres, the propellant composition of these strands being as follows:

nitrocellulose containing 11.7% of nitrogen:	54 parts
nitroglycerine:	36 parts
stabilisers:	2 parts

and 5 parts of combustion catalysts which make it possible to obtain, by means of the process of manufacture without solvent, the combustion characteristic at 20 degrees Centigrade, which is defined by the values:

V1 = 25 mm/second, P1 = 130 bars,
K1 = 250
V2 = 34 mm/second, P2 = 350 bars,
K2 = 400.

In the two comparison experiments carried out using this charge having an initial self-compression of 350, this charge is placed in a cylindrical combustion chamber having an internal diameter of 101 mm and the firings are carried out at + 20° Centigrade:

According to a first conventional mode of combustion, the combustion chamber is equipped with a nozzle having a neck of diameter 76.8 mm, which gives an initial coefficient of compression of 350, and the following values are recorded:

Maximum pressure PM = 480 bars
combustion time measured at 1/2 PM = 7 milliseconds
total combustion time measured at 5 bars = 25 milliseconds, and

in accordance with a second mode of combustion employing the present invention and not using any nozzle:

maximum pressure PM = 370 bars
combustion time measured at 1/2 PM = 7 milliseconds
total combustion time measured at 5 bars = 18 milliseconds.

These two comparison experiments show the surprising advantages which can be gained with the new mode of combustion, because, in addition to the omission of the nozzle, which makes it possible to produce a propulsion system with a much lighter body, the results show that, for an acceptable reduction in the total impulse, the maximum pressure recorded is substantially lower on the one hand, which makes it possible to lighten the cylindrical envelope withstanding the pressure, and, the final combustion time at low pressure is greatly reduced on the other hand, which makes it possible either to carry out the firing from a launching tube under conditions which are much more satisfactory in the case where the length of the tube is retained, or to reduce the length and the weight of the launching tube.

The course of the combustion of the charge in the acceleration stage shown in Fig. 1 is slightly different from the course of the combustion in the experiment indicated above, because there is added, to the main charge (10), the peripheral charge (11) of which the 85 tubular strands have a length of 115 millimetres and a propellant thickness which

is equal to half the thickness of the strands of the main charge, the external surface of these strands of propellant being covered with a thin layer of an inhibiting material making it possible for these 85 strands to have a surface area of combustion which increases during combustion, this reducing the degressive nature of the instantaneous coefficient of self-compression of the propellant charge during combustion.

The initial coefficient of self-compression of the propellant charge is ko = 330 and the repesentative line on the characteristic of the composition does indeed lie inside the zone (Z) of stable combustion, because it is located between the line representing the minimum coefficient of compression K1 and the line representing the maximum coefficient of compression K2. The theoretical initial speed of combustion is vo = 29 mm/second and the theoretical initial pressure is 190 bars; however, the actual initial speed of combustion and the actual initial pressure are substantially higher than these theoretical values, this being due to the phenomenon of erosive combustion which appears when the propellant charge possesses a very high coefficient of self-compression. During combustion of the charge, the thickness of the strands of propellant decreases and, as a result, the instantaneous free cross-section for ejection of the gases, measured in the region of the end of these strands, decreases greatly, whereas the surface area of combustion of the central strands (10) remains constant and the surface area of combustion of the peripheral strands (12) increases slightly. The instantaneous coefficient of self-compression (ki) of the charge therefore decreases rapidly and falls to a value which is very much less than the minimum coefficient of compression K1, which is equal to 250. The combustion therefore takes place in two successive stages, the first stage corresponding to ki>250 and taking place in the zone of stable combustion of the propellant composition, and the second phase corresponding to ki<250 and taking place in the zone of unstable combustion of the composition. This possibility of combustion in an unstable zone is still physically unexplained at the present time, but it is certain that the transitory phenomena which are difficult to study are the cause of this possibility and that the initial erosive combustion, and also the short duration of this second combustion stage, are necessary.

Fig. 3 shows the propulsion element of a self-propelled missile, the cruising stage of which is not shown and the launching tube of which is shown as fine dot-and-dash lines. The charge, which is only shown schematically, consists of 400 strands (31) which have the same cross-section as the tubular strands of the embodiment shown in Fig. 1, but the length of these strands is 240 mm, the front ends being embedded in a base-plate (32) made of an inhibiting material, which base-plate is stuck directly to the body of the propulsion system (33), which is reduced to a simple plate ensuring the transmission of the accelerating force to the cruising stage. This embodiment, which is particularly simple to produce, shows all the value of the new propulsion process which has been discovered, because the reduction in the dead weight of the rocket is particularly large and also enables the firing to take place under better conditions.

Fig. 4 shows a further embodiment of the invention, applied to the acceleration in flight of a semi-self-propelled missile which is initially fired from a barrel-type weapon which is not shown, the object of the acceleration stage (22) therefore being to effect an additional acceleration of the missile before ignition of the cruising stage (23). In accordance with this particular embodiment, the envelope which withstands the pressure of the gases forms the body (24) of the propulsion system, which is temporarily rendered integral with the cruising stage by means of a cylindrical centering device and four grooved shear pins, the breaking of which is gauged so as to ensure that the two stages remain integral for as long as the crusing propellant block (25), with a star-shaped central channel, is not ignited. The body of the propulsion system is approximately cylindrical and the cross-section of the opening for the ejection of the gases is equal to the cross-section of that zone of the body of the propulsion system which is arranged around the charge, this opening being temporarily blocked by an ejectable diaphragm (26) on which an annular igniter (27) is fixed. The propellant charge consists of sheets of propellant (28) arranged radially in the propulsion system, all these sheets having the same composition and the same thickness but possessing three different widths (w) so as to permit the imbrication which is necessary to obtain a small initial free cross-section, as measured at the level of the end (29) of the peripheral edge of the trapezoid-shaped sheets. As shown in the three-dimensional cross-section of Fig. 4, these sheets are provided on each of their faces with channels parallel to the axis of the propulsion system, and only these grooves are not covered with inhibitor, which makes it possible to obtain a propellant charge having an increasing surface area of combustion enabling the reduction in the instantaneous coefficient of self-compression of this charge to be decreased. The grooves have parallel sides and a semi-cylindrical bottom and their depth is such that the frame fronts issuing from these sides meet at the same instant as the flame fronts issuing from the bottoms of the grooves in the opposite faces, which makes it possible to limit the combustion residues. All the sheets of propel-

lant are laterally fixed by being embedded in the inhibiting shell (30) which is stuck to the body of the propulsion system, and intermediate supports for these sheets are provided in order to improve the wedging of these sheets during storage and during the stage of launching the semi-self-propelled missile from a barrel-type weapon.

CLAIMS

1. A propulsion unit for accelerating a self-propelled missile, comprising a body, a propellant charge including separate elements of propellant and carried on the body, and a generally cylindrical envelope surrounding the charge and capable of withstanding the pressure of the gases produced by combustion of the charge, the envelope including an opening for the ejection of the combustion gases from the envelope, the ignited surface area of the charge being between minimum and maximum values obtained by multiplying the initial free cross-section for the ejection of the gases, measured in the region of the ends of the elements of propellant, by the minimum and maximum coefficients of compression for the composition of the propellant of the elements, and the cross-section of the ejection opening being approximately equal to the cross-section of the envelope portion arranged around the propellant charge.

2. A propulsion unit according to claim 1, wherein the geometric conformation of the elements of propellant is such that, during combustion, the instantaneous surface area of combustion of the propellant charge becomes less than the minimum value obtained by multiplying the instantaneous free cross-section for the ejection of the gases, measured in the region of the ends of the elements of propellant, by the minimum coefficient of compression of the propellant composition used.

3. A propulsion unit according to claim 2, wherein the geometric conformation of the elements of propellant is such that the instantaneous surface area of combustion of the charge is less than the said minimum value for a period of time which does not exceed one second.

4. A propulsion unit according to any one of claims 1 to 3, wherein the cylindrical envelope forms part of the body of the propulsion system.

5. A propulsion unit according to claim 4, wherein the body is provided with a blocking device for closing the opening for as long as the ignition pressure of the propellant charge is not reached.

6. A propulsion unit according to any one of claims 1 to 3, wherein the cylindrical envelope consists of a part of a launching tube.

7. A propulsion unit according to claim 6, wherein the part of the tube has the form of a container having a rear opening closed by a blocking device adapted to free the opening when the ignition pressure of the propellant charge is reached.

8. A propulsion unit according to claim 7, wherein the blocking device is a frangible cover adapted to shear around a circumference corresponding to the internal surface of the container.

9. A propulsion unit according to any one of claims 1 to 3, wherein there are at least ten elements of propellant.

10. A propulsion unit according to any one of claims 1 to 3, wherein the elements of propellant extend parallel to the surface of the cylindrical envelope.

11. A propulsion unit according to any one of claims 1 to 3, wherein each element of propellant has a constant transverse cross-section.

12. A propulsion unit according to claim 11, wherein all the elements of propellant have the same transverse cross-section.

13. A propulsion unit according to any one of claims 1 to 3, wherein all the elements of propellant are of identical composition.

14. A propulsion unit according to claim 13, wherein the elements of propellant are produced from homogeneous propellant.

15. A propulsion unit according to any one of claims 1 to 3, wherein all the elements of propellant have the same combustion time,

16. A propulsion unit according to claim 9, wherein at least one element of propellant possesses a surface area of combustion which increases during the combustion of the propellant charge.

17. A propulsion unit according to any one of claims 10 to 16, wherein the elements of propellant are fixed to the body of the propulsion system via a layer of an inhibiting material.

18. A process for the acceleration of a self-propelled missile, consisting of burning a propellant charge, which comprises separate elements of propellant and is fixed to a body of the propulsion system, in an envelope which withstands the pressure of the gases produced by the combustion of the charge and has an opening for the ejection of the combustion gases from the envelope, and wherein, at the moment of ignition, the surface area of the charge is between the minimum and maximum values obtained by multiplying the initial free cross-section for the ejection of the gases, measured in the region of the end of the elements of propellant, by the minimum and maximum coefficients of compression for the composition of the propellant elements, respectively, and throughout the combustion of the charge, the cross-section of the ejection opening is approximately equal to the cross-section of the part of the envelope arranged around the propellant charge.

19. A process according to claim 18,

wherein during a first combustion stage, the instantaneous surface area of combustion of the charge is between the minimum and maximum values defined by the instantaneous free cross-section for the ejection of the gases, and during a second combustion stage, the instantaneous surface area of combustion of this charge becomes less than the minimum value obtained by multiplying the instantaneous free cross-section for the ejection of the gases, measured in the region of the ends of the elements of propellant, by the minimum coefficient of compression of the propellant composition used.

20. A process of acceleration according to one of claim 18 or 19, wherein a propulsion unit used for carrying out the process is in accordance with any one of claims 2 to 16.

21. A propulsion element of a propulsion unit according to claim 6.

22. A propulsion unit for accelerating a self-propelled missile, substantially as herein described with reference to the accompanying drawings.

23. A process for the acceleration of a self-propelled missile, substantially as herein described.

Printed for Her Majesty's Stationery Office
by Burgess & Son (Abingdon) Ltd.—1979.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.